through a plurality of rods. Thus, since it is configured such that the second joint is driven by a plurality of actuators and is connected to at least one of output shafts of the actuators and output shafts of transmission elements to which outputs of the output shafts of the actuators are transmitted, to be driven through a plurality of rods, the second joint is driven by a plurality of actuators and is connected to at least one of output shafts of the actuators and output shafts of transmission elements to which outputs of the actuators are transmitted, to be driven through a plurality of rods, in addition to the advantages mentioned above, the driving of the second joint (more specifically, the ankle joints which require large driving force) can be conducted using the sum of the driving forces of a plurality of actuators, and the actuators that drive the second joint can be made compact.

The present invention is further configured, as recited in claim 5 mentioned below, such that the rods are located to be spaced by prescribed distances from axes of the second joints. Thus, since it is configured such that the rods connecting the second joint and the outputs of the actuators (or the transmission elements to which their outputs are transmitted) are located to be spaced by prescribed distances from axes of the second joints, in addition to the advantages mentioned above, the second joint can be driven by a small force.

The present invention is further configured, as recited in claim 6 mentioned below, such that the second joint is one among the joints that the legs have, that is located farthest toward a ground-contacting end. Thus, since it is configured such that the second joint is one among the joints that the legs have, that is located farthest toward a ground-contacting end, the distance between the ground-contact end of the leg and the second joint (ankle joint) can be reduced, thereby enabling to improve the stability of the robot.

The present invention is further configured, as recited in claim 7 mentioned below, to have a legged mobile robot equipped with articulated legs such that it moves by driving each leg by an actuator associated therewith: characterized in that: each leg has at least a first joint, a second joint located below the first joint in the gravitational direction and a speed reducer to which an output of the actuator that drives the second joint is transmitted; and that an input shaft of the speed reducer is

located coaxially with an axis of the first joint. Thus, since it is configured such that each leg has at least a first joint, a second joint located below the first joint in the gravitational direction and a speed reducer to which an output of the actuator that drives the second joint is transmitted; and that an input shaft of the speed reducer is located coaxially with an axis of the first joint, it becomes possible to lighten the weight of the ground-contacting ends of the legs (distal end side, i.e., the side of the second joint) and thereby provide a legged mobile robot enabling reduction of the inertial forces occurring in the legs during moving, particularly during high-speed moving.

The present invention is further configured, as recited in claim 8 mentioned below, to have a legged mobile robot equipped with articulated legs such that it moves by driving each leg by an actuator associated therewith: characterized in that: each leg has at least a first joint, a second joint located below the first joint in the gravitational direction, a link that connects the first joint and the second joint, and a speed reducer to which an output of the actuator that drives the second joint is transmitted; and that a base of the speed reducer is located at the link that connects the first joint and the second joint. Thus, since it is configured such that each leg has at least a first joint, a second joint located below the first joint in the gravitational direction, a link that connects the first joint and the second joint, and a speed reducer to which an output of the actuator that drives the second joint is transmitted; and that a base of the speed reducer is located at the link that connects the first joint and the second joint, it becomes possible to lighten the weight of the ground-contacting ends of the legs (distal end side, i.e., the side of the second joint) and thereby provide a legged mobile robot enabling reduction of the inertial forces occurring in the legs during moving, particularly during high-speed moving. In addition, since a base of the speed reducer is located at the link that connects the first joint and the second joint, it becomes possible to reduce an influence that an angular change of the first joint gives to an angle of the second joint. Particularly, the angular change of the second joint with respect to the angular change of the first joint can be reduced in proportion to the reduction ratio of the speed reducer.

The present invention is further configured, as recited in claim 9 mentioned

below, such that an output shaft of the speed reducer is located coaxially with the axis of the first joint, and the second joint is connected to the output shaft of the speed reducer to be driven through a rod. Thus, since it is configured such that an output shaft of the speed reducer is located coaxially with the axis of the first joint, and the second joint is connected to the output shaft of the speed reducer to be driven through a rod, in addition to the advantages mentioned in Claims 7 and 8, driving force can be transmitted with good accuracy even though the second joint and speed reducer are located apart from each other, and the first joint and the second joint can be angularly adjusted independently.

The present invention is further configured, as recited in claim 10 mentioned below, such that the second joint has rotation axes that are arranged in at least two different directions. Thus, since it is configured such that the second joint has rotation axes that are arranged in at least two different directions, smooth moving of the robot is made possible.

The present invention is further configured, as recited in claim 11 mentioned below, such that the second joint is driven by a plurality of actuators and is connected to output shafts of the speed reducers to which outputs of the actuators are transmitted, to be driven through a plurality of rods. Thus, since it is configured such that the second joint is driven by a plurality of actuators and is connected to output shafts of the speed reducers to which outputs of the actuators are transmitted, to be driven through a plurality of rods, in addition to the advantages mentioned in Claims 7 to 10, the driving of the second joint (the ankle joint which requires large driving force) can be conducted using the sum of the driving forces of a plurality of the electric motors, the ankle joint electric motors thereby can be made compact.

The present invention is further configured, as recited in claim 12 mentioned below, such that the rods are located to be spaced by prescribed distances from axes of the second joints. Thus, since it is configured such that the rods connecting the second joints and the output shafts of the speed reducers are located to be spaced by prescribed distances from axes of the second joints, in addition to the advantage mentioned in Claim 11, the second joint can be driven by a small force.

The present invention is further configured, as recited in claim 13 mentioned

below, such that the second joint is one among the joints that the legs have, that is located farthest toward a ground-contacting end. Thus, since it is configured such that the second joint is one among the joints that the legs have, that is located farthest toward a ground-contacting end, in addition to the advantages mentioned in Claims 7 to 12, the distance between the ground-contact end of the leg and the second joint (ankle joint) can be reduced, thereby enabling to improve the stability of the robot.

BRIEF EXPLANATION OF THE DRAWINGS

FIG. 1 is a diagram schematically showing a legged mobile robot according to one embodiment of this invention with focus on the joint structure of the legs.

FIG. 2 is a right side view showing in detail the right leg of the legged robot shown schematically in FIG. 1.

FIG. 3 is a rear view of the leg shown in FIG. 2.

FIG. 4 is a sectional view taken along line IV – IV of FIG. 3.

FIG. 5 is a sectional view taken along line V – V in FIG. 3.

is connected through a belt 56v to a pulley 56p fastened to an output shaft 56os of the aforesaid second ankle joint electric motor 56, whereby the output of the second ankle joint electric motor 56 is transmitted to the speed reducer 72. The speed reducer 72 will be called a "second ankle joint speed reducer" hereinafter. The first ankle joint speed reducer 70 and second ankle joint speed reducer 72 are both known Harmonic Drives whose bases (sections that do not rotate) are fastened to the shank link 30R.

FIG. 4 is a sectional view taken along line IV – IV of FIG. 3, i.e., a sectional view of the knee joint 16R.

As shown in the same drawing, the input shafts 70is, 72is and output shafts 70os, 72os of the first ankle joint speed reducer 70 and second ankle joint speed reducer 72 are all located coaxially with the axis 16s of the knee joint 16R. Further, a first ankle joint rod connector 80 is fastened to the output shaft 70os of the first ankle joint speed reducer 70, and the upper end of a first ankle joint rod 82 made of a rigid body is connected to the first ankle joint rod connector 80 to be rotatable in the pitch direction. Similarly, a second ankle joint rod connector 84 is fastened to the output shaft 72os of the second ankle joint speed reducer 72, and the upper end of a second ankle joint rod 86 made of a rigid body is connected to the second ankle joint rod connector 84 to be rotatable in the pitch direction.

Returning to the explanation of FIG. 2 and FIG. 3, a mount 88 is provided above the six-axis force sensor 34R. A universal joint 90 equipped with rotation axes 90a and 90b in two different directions in the same plane is installed on the mount 88. The universal joint 90 is connected to the lower end of the shank link 30R, whereby it is connected to the aforesaid foot 22R through the universal joint 90, mount 88 and six-axis force sensor 34R. The universal joint 90 will be called a "shank link connecting universal joint" hereinafter.

FIG. 5 is a sectional view taken along line V – V in FIG. 3, i.e., a sectional view of the ankle joints 18R, 20R.

As shown in the same drawing, the shank link connecting universal joint 90 is equipped with two shafts 90A and 90B that intersect at right angles. The shaft 90A is a roll direction (around the X-axis) rotating shaft that corresponds to the aforesaid

joint 20R and whose center of rotation is the

changes by θmove.

On the other hand, in the legged mobile robot 1 according to this invention, change in the angle of the knee joint 16R(L) has substantially no effect on the angles of the ankle joints 18R(L), 20R(L). To be precise, the relative angle between the aforesaid base (section fastened to the shank link 30 that does not rotate) and the input shaft 70is, 72is changes when the angle of the knee joint 16R(L) changes, so that the ankle joints 18R(L), 20R(L) are driven in the pitch direction (around the Y-axis) by an angle reduced in proportion to the reduction ratio of the speed reducer 70, 72. Specifically, defining the change in the angle θknee of the knee joint 16R(L) as θmove, angle θankle of the ankle joint changes by approximately θmove / reduction ratio.

However, the reduction ratio of the speed reducers 70, 72 ordinarily needs to be set large because, as mentioned earlier, large driving forces are required for driving the ankle joints. θmove/reduction ratio therefore becomes a very small value, so that the change in the angle of the knee joint 16R(L) has substantially no effect on the angles of the ankle joints 18R(L), 20R(L). Moreover, since the rotational motion (rotational motion in the pitch direction) of the knee joint 16R(L) is totally unrelated to the rotational motion in the roll direction (around the X-axis) of the ankle joints 18R(L), 20R(L), the motion of the knee joint 16R(L) has no effect on roll direction motion of the ankle joints 18R(L), 20R(L). The knee joint 16R(L) and the ankle joints 18R(L), 20R(L) can therefore be angularly adjusted independently.

As set out in the foregoing, the legged mobile robot according to this embodiment is configured such that in a legged mobile robot (robot) 1 equipped with articulated legs such that it moves by driving each leg by an actuator associated therewith so as to be equipped with the articulated legs 2R(L) such that it moves by driving each leg by an actuator associated therewith, each leg has at least a first joint (knee joint 16R(L)) and a second joint (ankle joint 18R(L), 20R(L)) located below the first joint in the gravitational direction; and the actuator that drives the second joint (first ankle joint electric motor 54, second ankle joint electric motor 56) is located at least one of a position same as that of the first joint and a position (thigh links 28R(L)) above the first joint in the gravitational direction.

Further, it is configured such that, at least one of an output shaft (54os, 56os)